INTERNATIONAL STANDARD

ISO 20553

First edition
2006-04-15

Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material

Radioprotection — Surveillance professionnelle des travailleurs exposés à un risque de contamination interne par des matériaux radioactifs

Reference number
ISO 20553:2006(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 20553 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

Introduction

In the course of employment, individuals might work with radioactive materials that, under certain circumstances, could be taken into the body. Protecting workers against risks of incorporated radionuclides requires the monitoring of potential intakes and/or the quantification of actual intakes and exposures. The selection of measures and programmes for this purpose requires decisions concerning methods, techniques, frequencies etc. for measurements and dose assessment. The criteria permitting the evaluation of the necessity of such a monitoring programme or for the selection of methods and frequencies of monitoring usually depend upon the legislation, the purpose of the radiation protection programme, the probabilities of potential radionuclide intakes, and the characteristics of the materials handled.

This International Standard offers guidance for the decision whether a monitoring programme is required and how it should be designed. Its intention is to optimise the efforts for such a monitoring programme consistent with legal requirements and with the purpose of the radiation protection programme. Recommendations of international expert bodies and international experience with the practical application of these recommendations in radiation protection programmes have been considered in the development of this International Standard. Its application facilitates the exchanges of information between authorities, supervisory institutions and employers. The International Standard is not a substitute for legal requirements.

In the International Standard, the word “shall” is used to denote a requirement and no deviation is allowed. The word “should” is used to denote a recommendation from which justified deviations are allowed. The word “may” is used to denote permission.

Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material

1 Scope

This International Standard specifies the minimum requirements for the design of professional programmes to monitor workers exposed to the risk of internal contamination by radioactive substances and establishes principles for the development of compatible goals and requirements for monitoring programmes.

This International Standard addresses the

a) purposes of monitoring and of monitoring programmes;

b) description of the different categories of monitoring programmes;

c) quantitative criteria for conducting monitoring programmes;

d) suitable methods for monitoring and criteria for their selection;

e) information that has to be collected for the design of a monitoring programme;

f) general requirements for monitoring programmes (e.g. detection limits, tolerated uncertainties);

g) frequencies of measurements;

h) special cases;

i) quality assurance; and

j) documentation, reporting, record-keeping.

This International Standard does not address

— the monitoring of exposure to radon and its radioactive decay products;

— detailed descriptions of measuring methods and techniques;

— detailed procedures for *in vivo* measurements and *in vitro* analyses;

— interpretation of monitoring results in terms of doses;

— biokinetic data and mathematical models for converting measured activities into absorbed dose, equivalent dose and effective dose; or

— the investigation of the causes or implications of an exposure or intake.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

ISO 12790-1:2001, *Radiation protection — Performance criteria for radiobioassay — Part 1: General principles*

BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML, *International vocabulary of basic and general terms in metrology (VIM), 1993*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5725-1, ISO 12790-1 and *International vocabulary of basic and general terms in metrology (VIM)* and the following apply.

3.1 Absorption types

3.1.1
type F
F
deposited materials that have high (fast) rates of absorption into body fluids from the respiratory tract

3.1.2
type M
M
deposited materials that have intermediate (moderate) rates of absorption into body fluids from the respiratory tract

3.1.1
type S
S
deposited materials that have low (slow) rates of absorption into body fluids from the respiratory tract

3.2
accuracy of measurement
characteristics of an analysis or determination that ensure that both the bias and precision of the resulting quantity remains within specified limits

3.3
activity
transition rate

NOTE The activity is stated in becquerels (Bq).

3.4
activity median aerodynamic diameter
AMAD
value of aerodynamic diameter such that 50 % of the airborne activity in a specified aerosol is associated with particles smaller than the AMAD, and 50 % of the activity is associated with particles larger than the AMAD

NOTE The aerodynamic diameter of an airborne particle is the diameter that a sphere of unit density would need to have in order to have the same terminal velocity when settling in air as the particle of interest.

3.5
clearance
net effect of the biological processes by which radionuclides are removed from the body or from a tissue, organ or region of the body

NOTE The clearance rate is the rate at which this occurs.

3.6
contamination
activity of radionuclides present on surfaces, or within solids, liquids or gases (including the human body), where the presence of such radioactive material is unintended or undesirable

3.7
dose
[ICRU Report 60:1998]

3.7.1
annual dose
committed effective dose resulting from all intakes occurring during a calendar year

3.7.2
committed effective dose
time integral of the equivalent-dose rate over an integration period

NOTE In this International Standard, the integration time is 50 years following any intake.

3.7.3
effective dose
sum of the weighted equivalent doses in all tissues and organs of the body

NOTE The effective dose is expressed in units of joules per kilogram (special name: sievert, Sv).

3.7.4
total dose
sum of effective dose from external radiation and committed effective dose from internal radiation

3.8
excretion function
the fraction of an intake excreted per day after a given time has elapsed since the intake occurred

3.9
event
any unintended occurrence, including operating error, equipment failure or other mishap, the consequences or potential consequences of which are not negligible from the point of view of protection or safety

3.10
intake
activity of a radionuclide taken into the body in a given time period or as a result of a given event

3.11
***in vitro* analysis**
analysis including measurements of radioactivity present in biological samples taken from an individual

NOTE 1 These include urine, faeces and nasal samples. In special monitoring programmes, samples of other materials such as blood and hair may be taken.

NOTE 2 These analyses are sometimes referred to as indirect measurements.

3.12
***in vivo* measurement**
measurement of radioactivity present in the human body, carried out using detectors to measure the radiation emitted

NOTE 1 Normally the measurement devices are whole-body counters or part-body (e.g. lung, thyroid) counters.

NOTE 2 Sometimes also referred to as direct measurements.

3.13
investigation level
level of dose, exposure or intake (specified by the employer or the regulatory authority) at or above which an investigation is conducted

NOTE 1 See Clause 6.

3.14
detection limit
DL
smallest actual amount of a measurand that can be detected by a measuring method

NOTE Adapted from ISO 11929-7:2005.

3.15
monitoring
measurement of dose or contamination for the purpose of the assessment or control of exposure to radiation or radioactive material, and the interpretation of the results

3.15.1 Categories of monitoring programme

NOTE The present International Standard distinguishes four different categories of monitoring programme, namely **routine monitoring programmes** (3.15.1.1), **special monitoring programmes** (3.15.1.2), **confirmatory monitoring programmes** (3.15.1.3), and **task-related monitoring programmes** (3.15.1.4).

3.15.1.1
routine monitoring programme
systematic monitoring programme
monitoring programme associated with continuing operations and intended to demonstrate that working conditions, including the levels of individual dose, remain satisfactory, and to meet regulatory requirements

3.15.1.2
special monitoring programme
monitoring programme performed to quantify significant exposures following actual or suspected abnormal events

3.15.1.3
confirmatory monitoring programme
monitoring programme carried out to confirm assumptions about working conditions, for example that significant intakes have not occurred

3.15.1.4
task-related monitoring programme
specific monitoring programme
monitoring programme related to a specific operation, to provide information on a specific operation of limited duration, or following major modifications applied to the installations or operating procedures, or to confirm that the routine monitoring programme is suitable

3.15.2 Types of monitoring

NOTE This International Standard distinguishes two different types of monitoring in each category of monitoring, **individual monitoring** (3.15.2.2) and **workplace monitoring** (3.15.2.3). A further type of monitoring, **collective monitoring** (3.15.2.1), is regarded as a particular form of workplace monitoring.

3.15.2.1
collective monitoring
monitoring applied to representative members of a group of workers whose working conditions are not significantly different in terms of the risk of intakes

3.15.2.2
individual monitoring
monitoring by means of equipment worn by individual workers, or measurement of the quantities of radioactive materials in or on the bodies of individual workers, or measurement of radioactive material excreted by individual workers

3.15.2.3
workplace monitoring
monitoring using measurements made in the working environment

3.16
monitoring interval
period between two times of measurement

3.17
quality assurance
QA
planned and systematic actions necessary to provide adequate confidence that a process, measurement or service will satisfy given requirements for quality, for example, those specified in a licence

3.18
quality control
QC
part of quality assurance intended to verify that systems and components correspond to predetermined requirements

3.19
quality management
QM
all activities of the overall management function that determine the quality policy, objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance and quality improvement within the quality system

3.20
recording level
level of dose, exposure or intake (specified by the employer or the regulatory authority) at or above which values of dose, exposure or intake received by workers are to be entered in their individual exposure records

NOTE See Clause 6 for the reference levels.

3.21
reference level
investigation level or recording level

3.22
retention function
fraction of an intake present in the body or in a tissue, organ or region of the body after a given time has elapsed since the intake occurred

3.23
time of measurement
in the case of *in vitro* analysis, the time at which the biological sample (e.g. urine, faeces) was taken from the individual concerned. In the case of *in vivo* measurements, the time at which the *in vivo* measurement begins.

4 Symbols and abbreviated terms

AMAD	Activity median aerodynamic diameter
A_{DL}	Mathematical symbol for the detection limit, used in equations
DL	Detection limit
$e(50)$	Dose coefficient: committed effective dose accumulated within 50 years following a unit intake
$E(t)$	Value of the excretion function at time, t, (in days) after a unit intake
f_1	Gastro-intestinal uptake fraction
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
QA	Quality assurance
QC	Quality control
QM	Quality management
$R(t)$	Value of the retention function at time, t, (in days) after a unit intake
RPE	Respiratory protective equipment
ΔT	Time interval (in days) between two measurements in a routine monitoring programme

5 Purpose and need for monitoring programmes

The purpose of monitoring, in general, is to verify and document that the worker is protected adequately against risks from radionuclide intakes and the protection complies with legal requirements. Therefore, it forms part of the overall radiation protection programme, which starts with an assessment to identify work situations in which there is a risk of radionuclide intake by workers, and to quantify the likely intake of radioactive material and the resulting committed effective dose received. Decisions about the need for monitoring and the design of the monitoring programme should be made in the light of such a risk assessment.

Routine monitoring programmes are performed to quantify exposures where there is the possibility either of undetected accidental intakes or of chronic intakes. The basis for routine monitoring programmes is the assumption that working conditions, and thus risks of intake, remain reasonably constant. The design of such a programme of regular measurements strongly depends on the level of the annual dose the quantification of which is ensured. This level should be well below legally relevant limits; its definition should take into account uncertainties, for example in activity measurement and dose assessment. If this level is too high, intakes representing considerable fractions of dose limits could be overlooked, whilst a low value can cause the expenditure of unnecessary efforts at low exposures.

Special monitoring programmes are performed to quantify significant exposures following actual or suspected abnormal events. Therefore, in comparison to routine monitoring programmes, the time of intake is usually much better known and additional information can be available, which helps to reduce the uncertainty of

assessment. The purposes of dose assessment in such cases include assisting in decisions about countermeasures (e.g. decorporation therapy), compliance with legal regulations and aiding decisions for the improvement of conditions at the workplace. In most cases, special monitoring programmes are performed individually. In cases where there is reason to suspect that exposure limits could be exceeded, it can be appropriate to extend the measurements in order to derive individual retention and excretion functions and biokinetic model parameters.

Confirmatory monitoring programmes can be required to check the assumptions about exposure conditions underlying the procedures selected, e.g. the effectiveness of protection measures. It may consist of workplace or individual monitoring, e.g. as occasional measurements to investigate the potential accumulation of activity in the body.

Task-related monitoring programmes apply to a specific operation. The purpose and the dose criteria for carrying out task-related monitoring programmes are identical to those for routine monitoring programmes.

Individual monitoring gives information needed to assess the exposure of a single worker by measuring individual body activities, excretion rates or activity inhaled (using personal air samplers).

Workplace monitoring, which includes collective monitoring, provides exposure assessments for a group of workers assuming identical working conditions i.e. risks of intake as well as all factors influencing the resulting doses. It is mainly used in cases where individual monitoring is not appropriate and it can also be needed in those cases where individual monitoring is not sufficiently sensitive. In some cases, results of workplace monitoring are needed to support individual dose assessments (e.g. air monitoring can provide information on the time of an intake).

Factors determining the need for a monitoring programme are

— the magnitude of likely exposures;

— the need to recognise incorporation events should they occur;

— the need to assess the effectiveness of protective equipment (RPE).

Table 1 gives criteria defining the need for a monitoring programme, and this is illustrated diagrammatically in Figure 1.

The numbers given in this International Standard take into account only exposures by incorporated radionuclides. In cases where external exposure is likely to exceed the internal exposure, the values of Table 1 and Figure 1 are to be reduced by a factor of two.

Accordingly, it is necessary to assess the likely magnitude of exposures without taking into account personal protective measures. If available, this assessment can be done on the basis of results of earlier monitoring programmes (individual or workplace monitoring). If no other reliable information is available or can be obtained, the likely annual dose may be estimated according to the criteria suggested by IAEA Safety Reports Series No. 18[3] or on the basis of national guidelines.

Table 1 — Need for monitoring programmes according to the exposure situation

Type of monitoring required	Normative	Recommended level
Workplace monitoring	If the worker is occupationally exposed and the assessed dose contribution from intakes of radionuclides is likely to be significant	If the likely annual committed effective dose exceeds 1 mSv
Individual monitoring	If the worker can be exposed to more than 30 % of the dose limit by internal exposure	If the likely annual total dose exceeds 6 mSv

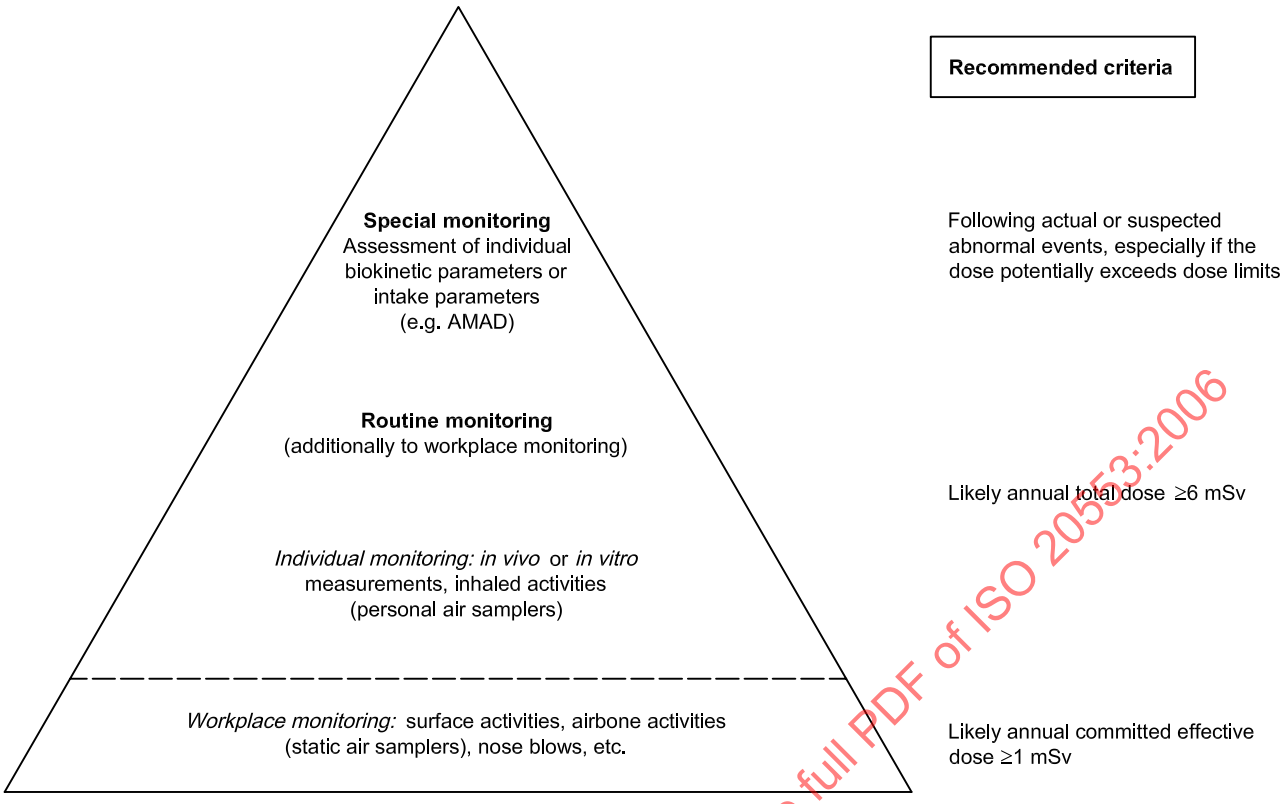

Figure 1 — Illustration of the need for monitoring programmes according to the exposure situation

If a worker is exposed to more than one radionuclide, the design of a monitoring programme may disregard radionuclides the sum of whose contributions in increasing order is likely to be less than 1 mSv per year.

In the case of mixtures where the radionuclide composition is well known, it is possible to use the measurement of a single radionuclide to infer the activities of the others. This approach is acceptable if the additional uncertainty (in terms of dose) arising from the incomplete knowledge of the radionuclide composition does not exceed 10 %.

6 Reference levels

Reference levels are the values of quantities above which a particular action or decision shall be taken. The purpose of setting these levels is so that unnecessary, non-productive work can be avoided and resources can be used where they are most needed. Reference levels include the recording level, above which a dose assessment has to be recorded, lower values being ignored; and the investigation level, above which the exposure estimates have to be confirmed by additional investigations (see Table 2).

NOTE The scope of this International Standard does not include the investigation of the causes or implications of an exposure or intake.

The recording level shall be set at a value corresponding (having regard to the length of the monitoring interval) to an annual dose no higher than 5 % of the annual dose limit. The investigation level shall be set at a value corresponding to an annual dose no higher than 30 % of the annual dose limit.

Table 2 — Reference levels for monitoring internal exposures

Level	Meaning
Recording level	The recording level is the level of dose, exposure or intake at or above which dose assessments have to be recorded in the individual exposure records. It shall be set at a value corresponding to an annual dose no higher than 5 % of the annual dose limit. Results falling below this level may be shown as "below recording level".
Investigation level	The investigation level is the level of dose, exposure or intake at or above which investigation has to be made in order to reduce the uncertainty associated with the dose assessment. The level shall be set at a value corresponding to an annual dose no higher than 30 % of the annual dose limit.

7 Routine monitoring programmes

7.1 General aspects

Routine monitoring programmes are established to quantify exposures where there is the possibility either of undetected accidental intakes or of chronic intakes. Measurements in a routine monitoring programme are made at pre-determined times and are not related to any known intake events. Decisions therefore have to be made in advance concerning methods, frequencies, and the underlying biokinetic models. For the evaluation of measured values in terms of intakes it also is necessary to make assumptions concerning the time interval between intake and measurement.

Routine monitoring programmes shall be established, including suitable workplace monitoring and individual monitoring according to the criteria in Table 1, taking into account the requirements of this clause.

The following general requirements shall be observed when specifying a routine monitoring programme:

— the consequences resulting from an unknown time interval between intake and measurement shall be limited so that

  — on average over many monitoring intervals, doses are not underestimated, and

  — the maximum underestimate of the dose resulting from a single intake does not exceed a factor of three, and

— the detection of all annual exposures that can exceed 1 mSv shall be ensured;

  NOTE For some radionuclides, this requirement can only be achieved by workplace monitoring.

— at least two measurements shall be performed annually.

The maximum overestimation is in nearly all cases greater than the maximum underestimation. The constraint on the maximum underestimation of a single intake does not exclude a considerable overestimation.

These requirements together with the assumptions about the pattern of intake and the sensitivity of the selected methods of measurement determine the frequency of the routine measurements.

The objectives of a monitoring programme and the way it is to be organized shall be documented according to Clause 11 including the basis for interpreting the results. The monitoring programme shall be reviewed by means of a confirmatory monitoring programme after any major modifications have been made to the installation, to operations, or to the regulatory requirements.

7.2 Workplace monitoring

Workplace monitoring includes collective monitoring (i.e. individual monitoring of selected workers representing groups of workers), and measurements of airborne activity and surface contamination in the workplace. Surface contamination is not directly related to individual exposure but can indicate increased risk of intake.

Continuous monitoring of airborne radioactive material is important, because inhalation is generally the main exposure pathway for workers. The main objectives of monitoring airborne activity are

— to help to assess the internal exposure of workers through inhalation;

— to rapidly detect abnormal or deteriorating conditions, thereby making it possible to take the appropriate protective action, for example, the use of respiratory protective equipment;

— to provide information for setting up individual monitoring programmes for workers.

The establishment of an air-monitoring system in order to detect and assess collective or individual exposure requires knowledge of the conditions at the workplace and the materials handled there. The design of the system is expected to be tailored to the risk of intake.

The results of air-monitoring can be used to estimate the intake of a radioactive substance by workers but reliance on measurement of airborne activities alone can lead to errors in exposure estimates. This is true when sources of air contamination are localized or change position over time, often because of worker action or movement.

Workplace air-monitoring results can be considered as representative provided they meet two criteria. Firstly, they reliably shall not underestimate the intakes as measured *in vivo* or by *in vitro* individual measurements. Secondly, they shall be confirmed by a confirmatory monitoring programme, involving the use of individual air-sampling devices or the use of individual excretion measurements.

NOTE The requirement to avoid underestimation may be achieved by applying correction factors taking into account spatial and temporal variability of radionuclide concentrations in the worker's breathing zone.

7.3 Individual monitoring

Individual monitoring of radionuclides can be made by *in vivo* measurements or *in vitro* analyses, by taking continuous air samples using individual air-sampling devices or by a combination of all these methods. The selection depends on a number of factors, such as the following:

— radiation emitted by the radionuclide and its progeny;

— decay rate of the radionuclide;

— retention in the body or the excretion rate from the body of the contaminant as a function of the time between intake and measurement;

— biokinetics, organ deposition and excretion pathway of the contaminant;

— technical feasibility of measurement.

The measurement frequency required for a routine monitoring programme depends on the retention and excretion of the radionuclide, the sensitivity of the available measurement techniques and the uncertainty that is acceptable when estimating annual intake and committed effective dose, as given in Equations (1) and (2):

For *in vivo* measurements:

$$e(50)\cdot\frac{A_{\mathrm{DL}}}{R(\Delta T)}\cdot\frac{365}{\Delta T}\leqslant 1\,\mathrm{mSv} \qquad (1)$$

For *in vitro* analyses:

$$e(50)\cdot\frac{A_{\mathrm{DL}}}{E(\Delta T)}\cdot\frac{365}{\Delta T}\leqslant 1\,\mathrm{mSv} \tag{2}$$

If exposure to more than one radionuclide cannot be ruled out, this requirement shall be adjusted accordingly so that a total annual dose of 1 mSv can reliably be detected and assessed. Small contributions may be ignored; see Clause 5.

The maximum potential underestimation shall not exceed a factor of three; assuming that a single intake occurred in the middle of the monitoring interval this requirement means, as given in Equations (3) and (4):

For *in vivo* measurements:

$$\frac{R(\frac{\Delta T}{2})}{R(\Delta T)}\leqslant 3 \tag{3}$$

For *in vitro* analyses:

$$\frac{E(\frac{\Delta T}{2})}{E(\Delta T)}\leqslant 3 \tag{4}$$

Individual air-sampling devices worn by workers can give an adequate estimate of the intake of each worker. However, they are susceptible to uncertainty resulting from the sampling of a single, non-representative particle. The interpretation of results can require a confirmatory monitoring programme to determine the distribution of particle sizes in aerosols. The presence of a few isolated high results from an individual air-sampling device indicates the need for a special monitoring programme.

Excretion analysis usually requires a 24 h sample collected in a manner that avoids external contamination. For certain elements, for which equilibrium is quickly reached between the blood and the urinary concentrations, it is also possible to take samples over shorter periods (“spot samples”) normalizing to 24 hour excretion on the basis of the creatinine concentration. Faecal excretion analysis is strongly recommended to be performed over three consecutive days.

In the case of material with very short effective half-lives (i.e. $< 0{,}5$ d), routine individual monitoring is in most cases not necessary, as the effective dose is dominated by the external exposure. However, there should be a considerable degree of confidence in the workplace monitoring system.

The measurement of nasal sample activity is another way to detect the inhalation of α-emitting particles; a positive result from such a measurement can be used as an indicator for further individual investigations for all the workers in the group. Such a measurement can also be useful for reducing the uncertainty in the time of an intake for dose assessment.

7.4 Methods and time intervals

The methods and time intervals summarized in this subclause were derived from the principles laid down above and the following assumptions:

— ICRP 66 [11] models for inhalation (default values for workers: AMAD = 5 µm);

— element-specific retention and clearance functions defined by ICRP 78 [12];

— acute intake by inhalation at the mid-point of the monitoring interval. This is a reasonable assumption for chronic intakes and, on average, it prevents the underestimation of intakes;

— with DL values of routine measurements as from ICRP 78.

The methods and time intervals for routine monitoring programmes are summarized in Table 3 for commonly used radionuclides. Other methods and time intervals may be used, if they fulfil the requirements defined above (see 7.1) and the above assumptions are shown not to be appropriate for particular cases. For other radionuclides, the methods and the time intervals of measurements shall be selected observing the requirements laid down above (see 7.1).

Table 3 — Methods and maximum time intervals for routine monitoring programmes

Radionuclide	Absorption type	*In vitro* analyses	*In vivo* measurements	
		Urine days	Whole body days	Thyroid days
^{3}H	HTO	30	—	—
^{14}C	Organic	7	—	—
	Dioxide	180	—	—
^{32}P	F	30	—	—
^{33}P	F	30	—	—
^{35}S	F	7	—	—
^{36}Cl	F	30	—	—
^{51}Cr	F	(15)	15	—
^{54}Mn	M	—	90	—
^{59}Fe	M	—	90	—
^{57}Co	S	(30)	180	—
^{58}Co	S	(90)	180	—
^{60}Co	S	(180)	180	—
^{63}Ni	M	15	—	—
^{75}Se	M	—	180	—
^{89}Sr	F, S	30	—	—
^{90}Sr	F, S	F:30, S:180	—	—
^{110m}Ag	S	—	180	—
^{125}I	F	(90)	—	90
^{131}I	F	(15)	—	15
^{137}Cs	F	(180)	180	—
^{226}Ra	M	180	—	—

NOTE Where a figure is given in brackets, this is an alternative to the value in a different column, for cases where in vivo measurements cannot be carried out.

For actinides, *in vivo* measurements or some *in vitro* techniques can only quantify exposures sufficiently reliably above 6 mSv. For the detection of lower exposures, if more sensitive in vitro techniques such as mass spectrometry are not available, workplace monitoring shall be applied.

If the dosimetry for actinides is based on the continuous monitoring of air samples, either static air samplers or, where likely intakes are higher, personal air samplers, should be used. These measurements shall be supplemented by individual methods, such as repeated nasal samples, to detect intakes requiring a special monitoring programme. Annual faecal analysis or lung counting methods are suitable to demonstrate that the air-monitoring does not underestimate the actual intakes. These methods are given in Tables 4 and 5. Where more than one method is indicated,

— the *in vivo* measurement, if available, should be the preferred method;

— urinary excretion analysis and *in vivo* measurements should be used for long-term, chronic exposure or if accumulations of small intakes cannot be ruled out;

— faecal excretion analysis should be selected for short-term exposures or changing working conditions.

Table 4 — Methods and maximum time intervals for routine monitoring programmes for uranium compounds

Material	Absorption type	*In vitro* analyses		*In vivo* measurements
		Urine days	Faeces days	Lungs days
Uranium hexafluoride	F	90	—	—
Uranium peroxide	F	30	—	—
Uranium nitrate	F	30	—	—
Ammonium diuranate	F	30	—	—
Uranium tetrafluoride	M	90	180	180
Uranium trioxide	M	90	180	180
Uranium octoxide	S	90	180	180
Uranium dioxide	S	90	180	180
NOTE Both the radiological and chemical toxicity of uranium compounds are taken into account. Faecal sampling is recommended to confirm that air sampling does not underestimate the actual intakes.				

Table 5 — Methods and maximum time intervals for routine monitoring programmes of compounds of actinides (except uranium)

Radionuclide	Absorption type	*In vitro* analyses		*In vivo* measurements
		Urine days	Faeces days	Lungs days
^{228}Th	S	—	180	—
^{232}Th	S	—	180	—
^{232}Th	M	—	180	—
^{237}Np	M	180	180	—
^{238}Pu	S	180	180	—
^{239}Pu	S	180	180	—
^{239}Pu	M	180	180	—
^{241}Am	M	180	180	180
^{244}Cm	M	180	180	—
NOTE Annual faecal sampling is recommended to confirm that air sampling does not underestimate the actual intakes; in this case, an interval of 365 days is sufficient.				

Tolerances for monitoring intervals based on practical considerations are given in Table 6.

Table 6 — Tolerances for different monitoring intervals

Monitoring Interval days	Tolerance days
7	± 1
15	± 2
30	± 4
60	± 7
90	± 14
180	± 30
365	± 30

8 Special monitoring programmes

8.1 General aspects

Special monitoring programmes shall be conducted following events to provide data for

— dose assessment required for estimating risk and determining the need for any treatment;

— radiation-protection optimization process.

In contrast to routine monitoring programmes, more information can be available about the circumstances of an intake event, especially relating to the time between measurement and the intake.

The objectives of a special monitoring programme and the way it is organized, including the basis for interpreting the results, shall be documented in accordance with Clause 11.

8.2 Workplace monitoring

Special monitoring programmes refer to measurements made when intake is suspected following an event. Special workplace monitoring is based on the same principles as for routine workplace monitoring and the same requirements shall be fulfilled (see 7.2).

The circumstances of each event are particular, for example, in the level of activity and duration of exposure, so it is difficult to standardize special workplace monitoring. The distribution of radioactive contamination should be assessed using air monitoring and surface contamination monitoring. Devices fitted with alarms and which operate continuously should be used whenever operations or malfunctioning is likely to produce significant releases of radioactive material in the workplace. The location of these devices should be chosen so that they can reliably detect the release of radioactive material; this is not necessarily at points that are representative of the workers' breathing area. The monitoring shall meet the general requirements defined in 7.2.

8.3 Individual monitoring

The goal of special individual monitoring is to ensure that any intake is detected at an early stage and that the associated committed doses are evaluated. Special monitoring programmes are investigative; they are usually based on a suitable combination of *in vivo* measurements and *in vitro* analyses in association with the appropriate biokinetic model.

— Nasal samples: The analysis of nasal samples (nasal smears or nose-blowing into cellulose tissues) can supplement a special monitoring programme in order to give a rapid estimate of the severity of an event and valuable information on the nature of the inhaled contaminant. However, activity of these samples represents activity that has been removed from the body before becoming part of a systemic uptake.

— *In vivo* measurement: The radionuclide content of the body is quickly available and gives an indication whether a significant intake has occurred.

— *In vitro* analysis: The choice between urine and faecal monitoring depends on the biokinetics of the materials incorporated, which directly depends on the chemical form. Large fluctuations in the faecal excretion of radionuclides from one day to the next give rise to uncertainty when interpreting the results. Consequently, faecal samples should preferably be collected over a period of about three days to reduce this uncertainty. Faecal samples collected soon after intake include non-systemic activity from lung clearance to the GI tract or directly from ingestion. While amounts can fluctuate greatly, the fraction of intake in those samples is relatively large and there is a greater chance of detection of low-level intakes of actinides and other radionuclides. Faecal analysis is appropriate in the case of a suspected intake of compounds of absorption types M or S. In these cases, faecal excretion analysis may be used for assessing transfer to the gut from the lungs and hence estimating intake. For materials with long retention in the lung, repeated analysis throughout the year should be performed to confirm the results, since interpretation based on a single isolated result can be unreliable. Usually, a reliable dose assessment on the basis of urinary analysis requires a 24 h sample; but in the case of special monitoring programmes, it can be helpful to collect “spot samples”.

— Exhalation monitoring: ^{220}Rn exhalation measurement allows the individual determination of ^{228}Th body burdens without chemical preparation. The detection limit of this method is comparable to that of urinary excretion analysis. Conclusions concerning ^{232}Th quantification require additional information about the nuclide spectrum.

Table 7 summarizes recommended methods for individual monitoring; it does not take into account the effects of treatment that can be undertaken to reduce the committed effective dose.

Table 7 — Recommended methods for special monitoring programmes after inhalation

Radionuclide/material	Nasal		*In vitro* analyses			*In vivo* measurements		
			Urine		Faeces	Organ		
	NS	EA	Spot sample	24 h	72 h	WB	L	Th
^{3}H	**		**					
^{14}C		**	**	*				
^{32}P			**	*				
^{33}P			**	*				
^{35}S			**	*				
$^{36}Cl^{\dagger}$				**		**		
^{51}Cr	**			**		**		
^{54}Mn	**			**	**	**		
^{59}Fe	**			**		**		
^{57}Co	**			**		**		
^{58}Co	**			**	**	**		
^{60}Co	**			**	**	**		
^{63}Ni	**			**		**		
^{75}Se	**					**		
^{89}Sr	**			**				
^{90}Sr	**			**				
^{110m}Ag	**			*	**	**		
^{125}I	**			**				**
^{131}I	**			**				**
^{137}Cs	**			**	*	**		
^{147}Pm	**			**				
^{226}Ra	**			**				
Uranium hexafluoride	**		**	**				
Uranium peroxide	**		**	**				
Uranium nitrate	**		**	**				
Ammonium diuranate	**		**	**				
Uranium tetrafluoride	**		**	**	*		*	
Uranium trioxide	**		**	**	*		*	
Uranium octoxide	**			**	**		**	
Uranium dioxide	**			**	**		**	
^{228}Th	**	**		**	**		*	
^{232}Th	**	*		**	**		*	
^{237}Np	**			**	**			
^{238}Pu	**			**	**			
^{239}Pu	**			**	**			
^{241}Am	**			**	**		**	
^{244}Cm	**			**	**			

** = Recommended, * = Supplementary (helpful but not mandatory)

Legend: NS = Nasal sample EA = Expired air WB = Whole Body L = Lung Th = Thyroid

† In vivo measurement makes use of the bremsstrahlung.

9 Task-related monitoring programmes

9.1 General aspects

Task-related monitoring programmes are required in the case of changes in working conditions and operations of limited duration (i.e. the duration is shorter than the intervals defined for routine monitoring programmes in Clause 7, Tables 3, 4 and 5) to provide data for dose assessment and for the radiation protection optimisation process. The general requirements set out in 7.1 for routine monitoring programmes shall be applied to task-related monitoring programmes.

When the operation is planned, an appropriate monitoring programme shall be devised. This is also necessary after major modifications have been applied to the installations or operating procedures.

This task-related workplace monitoring (measurement of airborne activity, surface wipe tests, etc.) complements individual monitoring, since it provides useful indicators for predicting doses and for establishing protective measures for the operation. However, individual monitoring gives more reliable dose estimates.

In contrast to routine monitoring programmes, more information can be available about the circumstances of an intake event, especially relating to the time between measurement and the intake.

The objectives of a task-related monitoring programme and the way it is organized, including the basis for interpreting the results, shall be documented according to Clause 11.

9.2 Workplace monitoring

Workplace monitoring is based on the same principles as for routine workplace monitoring and the same requirements shall be fulfilled (see 7.2).

The establishment of an air-monitoring system in order to detect and assess collective or individual exposure requires knowledge of the conditions at the workplace and the materials handled there. The design of the system needs to be tailored to the risk of intake.

There can be significant differences between the level of airborne contamination in the worker's breathing area and the level measured at a fixed spot close by, contamination in the breathing area usually being higher. It is essential that this factor be recognized when programmes for monitoring airborne contamination at the workplace are being devised (see also 7.2).

9.3 Individual monitoring

Individual monitoring as part of task-related monitoring programmes normally takes the form of confirmatory monitoring programmes. This serves to confirm the adequacy of protective measures and of assumptions made regarding the levels of exposure. In normal conditions, an individual task-related monitoring programme is not necessary as regards internal exposure provided suitable individual protection is used during the tasks. Nonetheless, a special monitoring programme can be required if there is evidence that the protective measures have failed. Special monitoring programmes of high-risk work can require the setting in place of a series of suitable measurements combining several measurement techniques. Periodic measurements can be made to ensure that working conditions are satisfactory. In association with radiation-protection departments, the results of workplace monitoring (wipe tests and air sample measurements) and contamination measurements made on individuals can be compared and the radiation protection system modified if need be. An analysis of faecal matter over the last three days of worksite operation can be appropriate.

10 Special cases of individual monitoring

10.1 Actinides

The detection limits associated with particular analytical techniques and the uncertainty of measurement and interpretation make it difficult to evaluate intake rapidly. All of the above also lead to uncertainty in the assessment of the internal dose received by each worker. Individual monitoring takes the form of lung counting and monitoring of urinary and faecal excretion or exhalation.

In vivo detection of the intake of actinides using lung counting is based on the detection of x-ray photons with characteristic energy levels. However, this method offers a poor level of sensitivity due both to the low intensity of the x-ray photons emitted and attenuation by the tissues and to the high background due to other radionuclides present. Thus, for many radionuclides, the detection limits are above regulatory limits. Lung counting is, therefore, not sufficient as a means of routinely measuring small intakes and is used to supplement other methods, especially air monitoring; air monitoring is the most reliable especially for cases for which particle sizes and solubility are not well known.

10.2 Contamination in wounds

Cuts and grazes on the skin and puncture wounds allow radioactive material to penetrate the subcutaneous tissue and then infiltrate into the rest of the body. Depending on the radionuclides and the quantity of material, it may be necessary to conduct a medical examination and a special monitoring programme. In this case, the activity of radioactive material at the site of the wound has to be measured, taking account of attenuation of the radiation by foreign matter and tissues in order to assess the dose to local tissues and to decide whether or not excision is required. If the decision is taken to attempt to remove the material from the wound, the activity removed and the activity remaining around the wound have to be measured to obtain an activity balance. Furthermore, a series of measurements has to be made to determine the uptake of activity to the rest of the body. In the interest of reliable dose assessment, all methods applicable for the incorporated radionuclides, *in vivo* measurements and *in vitro* analyses, shall be applied. If *in vivo* measurements are made, the activity remaining around the wound may have to be shielded to avoid interference. To assess the committed effective dose, allowance should be made for the effect of any treatment administered to accelerate the excretion of systemic activity.

10.3 Contamination on the skin

Contamination on the skin can result in an intake of the radionuclide into the body. This especially shall be taken into account for tritium, iodine, caesium and some organic compounds. Therefore, for radionuclides for which contamination is directly measurable, a level for skin contamination shall be defined above which a special monitoring programme of intakes is required. For other radionuclides not directly measurable, a routine monitoring programme of intake shall be performed.

11 Recording, documentation and reporting

11.1 Recording and documentation

11.1.1 General

The strategy and objectives for monitoring workers occupationally exposed to radioactive material shall be documented. For some radioactive material, a single method of measurement sufficients. In such a case, it is enough to lay down the frequency of sampling/measurement and the assumptions used in calculating the dose received from the results of the measurements. In other cases, a range of measurement methods can be necessary, including air-sampling, urine and/or faecal sampling, and part or whole-body monitoring. In these cases, the strategy shall set out the purpose and frequency of each type of measurement and the way the results are used in assessment of the dose received.